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LAKE ERIE SICK DYING OR WELL

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LAKE ERIE - SICK, DYING, OR WELL*

by

C. W. Northington**

Is Lake Erie dying?

To the biologist what is the answer? There is more life in Lake Erie today than ever before, and a greater abundance of life is expected as the Lake becomes older and richer. However, organisms now present do not indicate a healthy body of water.

To the water supply man and to industry the answer is again, no. Water quality at intakes is excellent for industrial and municipal needs as measured by accepted water quality indicators.

But to fishermen, both commercial and sportsmen, the answer is yes.

To swimmers, to boaters, to lakefront property owners and many other nature lovers the answer is again, yes.

Walleye, pike, and cisco have been virtually replaced by less desirable fishes. The commercial fish catch from Lake Erie has dropped from over half the Great Lakes total to less than the catch from Lake Michigan alone. Many commercial fishermen have become destitute.

To them Lake Erie is dying.

Tremendous algal growths die and wash ashore forming great odorous masses of organic material around boat docks, lakefront property, and bathing beaches.

Kelley's Island; Erie, Pennsylvania; Silver Creek and Dunkirk, New York are some areas that have suffered seriously from these conditions.

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Debris, logs, lumber, tree stumps, and anything else that will float or that can be moved by wave action litter the Lake shoreline.

Bathing beaches around Cleveland, Silver Creek, Dunkirk and many other areas are contaminated by coliform bacteria from sewage.

Why then doesn't someone do something to save Lake Erie?

The answer to this question is more direct. Someone is doing something. You people here today are doing something. Hundreds of thousands more are signing petitions, writing government officials, forming Save Lake Erie clubs, and instituting clean water campaigns.

Your clean water prospecting has struck gold. President Johnson, in his Natural Beauty Message to Congress, set the tone for things to come when he singled out Lake Erie as a special problem.

Congress is expressing its concern through various pieces of water pollution control legislation. Paramount among this legislation is a revision of the Federal Water Pollution Control Act designed to make the program more responsive to the needs of modern society.

State and local authorities have not been immune to your messages either. Bold new water pollution control programs are being proposed by states and by local authorities. Governor Rockefeller has asked for a 1.7 billion dollar program in New York State. Mayor Locher of Cleveland has asked for a similar program in Ohio.

Even before these public pressures became so great, the water pollution problems in the Great Lakes system were singled out by the Department of Health, Education, and Welfare for special attention. The Great Lakes-Illinois River Basins comprehensive program was established in 1960 by authorization provided in the Federal Water Pollution Control Act, as amended.

The purpose of this comprehensive program is to protect public health and to meet the public desires for water quality. The objective is to cooperate with state, local, and interstate agencies, interested Federal agencies, municipalities, industries and the public in setting up continuing programs to meet these needs for water quality.

The Great Lakes-Illinois River Basins Project area is divided into six parts, comprising the drainage basins of the Illinois River, Lake Michigan, Lake Superior, Lake Huron, Lake Erie, and Lake Ontario (the latter to include the St. Lawrence River Basin to the International Boundary).

The Lake Erie Basin program began in October 1962 with headquarters in Parma, Ohio.

The Lake Erie Basin is being divided into packages or units having common water quality desires and common water resources or hydrology. Water pollution control programs are being developed for each unit. The unit programs will then be welded into a larger program which will be principally concerned with the Lake itself.

The water pollution control program for each unit and for the Lake will consist of two bases: (1) a technical base from which information necessary for making decisions relative to water quality can be drawn and, (2) a social base for stimulating decision making and producing commands.

The social base will consist of three general interest groups:

1. Agencies with legal authority in water pollution control - state, interstate, Federal, and local.

2. Water users - municipal, industrial, recreational, fish and wildlife, agriculture, et cetera.

3. Participators - those agencies, municipalities, industries, colleges, universities, et cetera who furnish technical information and technical advice to the program.

The technical base will consist of: (1) a pool of knowledge, (2) equipment, (3) techincal and scientific personnel, (4) water quality models, (5) economic decision models, (6) water quality goals, and (7) an operating program. The technical base will be equipped to tell the social base how to obtain any given water quality and how much it will cost.

Actually, the comprehensive program for water pollution control is not something new. Since man began to congregate, there has been some program for fighting pollution. However, control inputs have been sporadic in the past. The present day concept of comprehensive programs is twofold: (1) to make an intensive input and raise the water pollution control efforts to the level necessary to protect public health and to meet public desires for water quality, and (2) to make provisions for a continuing program to maintain the desired water quality.

The comprehensive program has an intensive phase and a continuing phase. The intensive phase of the Lake Erie Basin program is scheduled to be completed by July 1966, and that for the entire Great Lakes by July 1967.

The intensive phase consists of building the two bases - technical and social. The social base is being built by forming committees composed of representatives of the three general interest groups - water pollution control authorities, water users and participators. There will

be one base for the Lake with subgroups for each major hydrological unit. The major functions of these social bases will be to make decisions on water quality desires and to give the necessary commands to obtain this water quality; thus, putting the choice of water quality into the hands of the people.

The technical base is being formed by collecting necessary information on sources of wastes and their effects on water quality, constructing water quality models and economic models, establishing water quality goals, training personnel, designing a master control plan, and designing a technical organization to continually update the plan and technical base.

One of the major activities in forming the technical base is defining the water quality problems and their causes. Most of the project energies to date have been confined to this task. Extensive field programs have been conducted on the Lake and its major tributaries to determine the effects of pollution on water quality and water uses.

Lake Erie has been sampled from end to end, side to side, and top to bottom. The water and bottom muds have been analyzed for chemical constituents, microorganisms - plant and animal, and macroorganisms - plant and animal. Major tributary streams have been subjected to this same intense study.

Over 250,000 analyses have been made for coliform, fecal coliform, fecal strep, enteric pathogens, toxic materials including pesticides, algae and other aquatic plants, bottom dwelling organisms, free-floating organisms, biochemical oxygen demand, dissolved oxygen, temperature, oil, nitrogen, phosphorus, and about 40 other minor chemicals. Observations of debris and refuse have been recorded. Unmanned instruments located in the Lake are continually recording current direction, speed and water temperature, even under the ice cap. Wind direction, speed, and temperature and rainfall are recorded by these instruments when the Lake is not frozen.

Although we do not have all the answers, we have made enough evaluations to make some general observations relative to the effects of pollution on water quality and water uses in the major problem areas within the basin and the Lake itself.

Although some polluting materials are produced in the Lake, practically all wastes originate from land based activities of man. All major tributaries to Lake Erie are grossly polluted at their mouths and many are grossly polluted throughout large portions of their lengths.

For the sake of simplicity, I shall discuss the rivers in hydrological sequence beginning with the St. Clair River and following the American shoreline to Niagara Falls. After I talk of the rivers, I will discuss the Lake itself.

The [illegible] River water [illegible] for all [illegible] consistently exceed 1,000/100 ml. [illegible] phosphorus, and nitrogen are very low and are not considered a problem.

The Belle River exhibits a high median coliform density of 29,000/100 ml.

Lake St. Clair water quality is good for usual purposes except for local effects from the Clinton River which tend to hug the western shore from Anchor Bay to the Detroit River.

The dissolved oxygen occasionally drops below 2 mg/l in the Clinton [illegible] between Pontiac and Lake St. Clair. Average coliform counts of [illegible]/100 ml and bio-chemical oxygen demand along with 2,800 tons/year of nitrogen and 1,800 tons/year of phosphorus are contributed to the Clinton River by municipal treatment plants and combined sewers.

The Detroit River, Huron River, and Raisin River and the Michigan portion of Lake Erie are subjects of a special type water pollution control program known as a Federal enforcement action and, therefore, will not be discussed in detail in this paper.

However, I will generalize a little and say that the Detroit River as it flows southward toward Lake Erie has wastes added to the extent that it is significantly polluted by the time it reaches Lake Erie.

The Maumee River system which drains portions of Indiana, Michigan, and Ohio is characterized by extremely low flows during most of the year with concurrent serious dissolved oxygen problems below most all municipal outfalls, although all major cities except Defiance, Ohio have secondary treatment for municipal sewage.

Coliform densities are high throughout the system. Taste and odor problems persist in municipal water supplies and frequently render the water unfit for food processing resulting in high economic losses. Many serious fish kills are caused by low dissolved oxygen and toxic wastes. Soil and bank erosion occur throughout the system resulting in high silt loads filling the navigation channel and eventually reaching into Lake Erie. Fish kills along with annihilation of spawning beds by silt have resulted in an almost complete loss of the basin's sport fisheries. Algae and debris abound in most sections of the Maumee River and its tributaries.

The Auglaize River is the most seriously polluted tributary to the Maumee River. Pollution from Lima, mostly industrial, renders the Ottawa River a [illegible] open sewer until it empties into the Auglaize about 40 miles above Defiance. In this stretch of the Ottawa, the dissolved oxygen content is almost continuously zero in spring, summer, and fall.

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Ammonia concentrations of 80 mg/l and cyanide concentrations of 1.0 mg/l were measured last December. Fifteen mg/l of ammonia or 0.2 mg/l of cyanide will kill many species of fish. At the same time in December over 750,000 fish died in the Auglaize River between the Ottawa confluence and Defiance where ammonia concentrations of 25 mg/l and cyanide concentrations of 0.35 mg/l were measured.

Coliform densities on the Ottawa were as high as 500,000/100 ml. Threshold odors of over 400 and significant concentrations of pesticides were found. Frequently large slugs of oil blacken the entire Ottawa River and stretches of the Auglaize River.

The Blanchard River, another part of the Auglaize, had such serious dissolved oxygen problems below the town of Ottawa last fall that paint on nearby houses was turned black by the hydrogen sulfide gases given off. Intermittent discharges of wastes by the guilty industry caused the dissolved oxygen content in the Blanchard River to fluctuate from good to zero. As a result, fish from the Auglaize would come up the Blanchard and be trapped when the oxygen dropped again. Consequently, a series of fish kills here destroyed nearly a million fish last year.

Before leaving the Auglaize system let me say that the industries causing the most serious problems on the Blanchard and the Ottawa have improvements underway that will give considerable relief.

The St. Marys River rising in Ohio and the St. Joseph River rising in Michigan meet in Ft. Wayne, Indiana and form the Maumee River. In the St. Joseph the water quality is good except for low dissolved oxygen and coliform below Montpelier. Dissolved oxygen concentrations below 4 mg/l frequently occur below the cities of St. Marys and Decatur where municipal wastes also cause high coliform counts. Part of the biochemical oxygen demand comes from tire and rubber industries, food processing plants and canneries.

When these two rivers converge and Ft. Wayne with its industries adds its wastes burden, the troubles in the Maumee begin. Water quality progressively worsens as towns, industries, and tributaries pour in their waste loads. Shortly below Ft. Wayne, the dissolved oxygen drops to near zero in the summer, recovers fairly well by the time it reaches Defiance, takes another sharp drop to near zero at times, then recovers quickly until it reaches Napoleon where the dissolved oxygen drops to 4 mg/l, then recovers until it reaches Toledo. Coliform counts are extremely high from Ft. Wayne to Lake Erie, densities from 2,400 to 2,700,000/100 ml being common occurrences.

Phenols up to 0.14 mg/l are found below Ft. Wayne and up to .052 mg/l below Defiance. Up to 60 mg/l of ammonia is found from Defiance to the navigation channel in Toledo.

Taste and odor problems in the Defiance water system appear to correlate with occurrences of high phenol concentrations below Fort Wayne. At times algae blooms in the area of the water intake have caused these problems. All water supplies below Defiance report serious problems with tastes and odors attributed to phenols, ammonia, algae and actinomycetes (fungi type growth). Tremendous algal blooms create unsightliness, and at times add to the dissolved oxygen problem which adversely affects the fisheries and, along with coliforms, oil and debris, degrade the water for boating, swimming, and skiing.

With about half the study complete, it appears that the major pollution problems in the basin originate in the Auglaize system, mainly from the Lima area. Wastes from other municipalities, industries, and agriculture are also important sources of pollution. The nutrients, leached from farmlands and added to those from municipal wastes and from industries, in addition to creating problems in the river, eventually reach Lake Erie adding to its already excessive enrichment.

The Maumee River is somewhat degraded as it reaches Toledo. Although dissolved oxygen rarely drops below 5 mg/l, biochemical oxygen demand varies from 1 to 15 mg/l, total solids average 500 mg/l, and coliforms average 16,000/100 ml with a maximum count of 220,000/100 ml.

The water, already in poor condition, enters the river navigation channel and becomes further degraded by additional wastes from industries, overflowing sewers, drainage from septic tanks and effluent from the Toledo sewage treatment plant. Yes, effluent from the Toledo sewage treatment plant, although discharged into the navigation channel in the bay area, is washed back into town by the estuary type actions from seiches and wind tides. Sampling analyses indicate effects of the sewage treatment plant are felt above Swan Creek. Reverse flows were observed as much as 15 miles upstream from the Lake.

Water quality in the navigation channel is characterized by coliform counts up to 1,400,000/100 ml, frequent near zero dissolved oxygen, floating debris, algal growths, oil and scum.

The Portage River pollution problems, primarily from municipal wastes and silt, are not considered serious. However, problems of low dissolved oxygen and septic conditions are reported below Bowling Green and Fostoria. Coliform counts range up to 1,000,000/100 ml at Port Clinton. Sediment loads to Lake Erie range up to 32,000 tons per month during the spring.

The Sandusky River problems are primarily from municipal wastes including runoff and discharges from unsewered areas. These wastes result in high coliform counts often exceeding 100,000/100 ml below Fremont. Low dissolved oxygen conditions were found below Upper Sandusky and Fremont, frequently reaching near zero during late summer. Nuisance conditions were reported in many small streams through unsewered populated areas. Algal problems were reported by water works operators.

The Black River pollution begins in its upper reaches, where heavy algal growths, debris, trees, tree stumps, and refuse clog the streams. From Elyria to the Lake, municipal and industrial wastes add to the already defiled stream. Coliform counts often exceed 100,000/100 ml at various sampling points between Elyria and Lake Erie. Oil slicks, vapor from thermal discharges and debris are visible in Lorain.

The problems in the Rocky River basin are mainly high coliform counts, low dissolved oxygen, and debris, principally from inadequate municipal waste treatment and debris of civilization. Coliform counts well above 5,000/100 ml and up to 490,000/100 ml were found throughout the stretches through the Metropolitan Park system. Numerous reports of odors at several points within the urban area have been received. Accumulations of floating debris and raw sewage create a nuisance and a hazard to the recreational area near the Lake.

The Cuyahoga River problems begin below Rockwell Dam where median coliform counts reach 160,000/100 ml before it reaches Akron, 200,000/100 ml below Akron and above 1,000,000/100 ml before it reaches Lake Erie. Dissolved oxygen frequently drops to zero at points below Kent, Ravenna, Stow, Munroe Falls, and between Akron and the navigation channel where it seldom gets above 2 ppm during the warm seasons. The river between Akron and Cleveland is cluttered with fallen trees, tree stumps, trash, and floating debris. Waste dumps ranging in size from "one shot" affairs to sanitary landfills, are found whenever the river meanders close to an access road. Heavy growths of algae are found in the small impoundments above Akron.

The water quality conditions in the Upper Cuyahoga River are caused principally by municipal wastes and low stream flows, aided and abetted by industrial wastes. Nature and man together furnish the debris, stumps, trees, refuse, et cetera. As a result, fishing, boating, skiing and water supply uses between Rockwell Dam and Akron are impaired. Below Akron the water is used only for rough fish, industrial water and waste transport.

The navigation channel of the Cuyahoga River is characterized by almost continuous zero dissolved oxygen in the warm months, a reddish iron color, oil, scum, dead trees, lumber, debris, thermal pollution, sediment and acidity with a pH below 7 most of the time and coliform counts reaching 48,000,000/100 ml. This abnormally high coliform count is caused by combined sewer overflows and a broken sewer on Big Creek. There is no visible aquatic life in this reach.

Part of this problem originates in the upper reaches and in the suburban areas. However, most of the coliform, most of the biochemical oxygen demand, and a portion of the oil comes from combined sewer overflows, broken sewers, malfunctioning septic tanks and from the Southerly sewage treatment plant. The reddish color, part of the oil, part of the sediment, some biochemical oxygen demand, some debris, acidity and thermal pollution come from industries. Ninety-two percent of the people in the Cuyahoga basin are served by treatment plants classified as inadequate

by the Ohio Water Pollution Control Board. Fortunately, corrections on all these are either under construction or are being planned. Forty-five percent of the industrial plants discharging directly to the streams are classified as having inadequate waste treatment. Many of these are now making improvements.

Pollution in the navigation channel not only renders it unsightly but causes hazardous conditions as well. Uses are limited to navigation, industrial (mostly cooling), and waste transport.

The Chagrin River appears to be in good condition except for coliform counts above 10,000/100 ml in Willoughby.

The Grand River pollution problems are confined mainly to chloride concentrations reaching up to 6,000 mg/l and coliform counts exceeding 100,000/100 ml in the Fairport-Painesville area. Chlorides are contributed by chemical industries while the coliforms are contributed by municipal wastes.

The Ashtabula River in Ashtabula is polluted with coliform concentrations exceeding 100,000/100 ml, and chloride concentrations up to 450 mg/l. Dissolved oxygen frequently drops below 4 mg/l.

Chlorides are contributed by industries while the coliform counts and biochemical oxygen demand are presently unexpalined.

Mill Creek and Cascade Creek near Erie are examples of small streams in Pennsylvania that are grossly polluted by industrial and municipal wastes. Coliform counts of over 1,000,000/100 ml were found in Mill Creek. Fortunately, most of the small streams in Pennsylvania are of fairly good quality and support fish and other aquatic life.

Chautauqua Creek, Canadaway Creek, and Silver Creek in New York are polluted at times mainly from domestic sewage. Silver Creek shows visible evidence of pollution in its lower reaches and is often septic.

Cattaraugus Creek is polluted below Arcade, Gowanda, and near its mouth. pH values of 6.7, dissolved oxygen of 1.6 mg/l, and biochemical oxygen demand of 162 mg/l have been recorded below Gowanda. Dissolved oxygen drops to zero and coliforms climb to nearly 500,000/100 ml near its mouth.

Industries, municipalities and refuse dumps are the sources of pollution in Cattaraugus Creek.

Eighteen Mile Creek is polluted near Hamburg where sewage plant effluent and home disposal effluent lowers the dissolved oxygen and raises the coliform count.

The Buffalo River system includes Cazenovia Creek, Cayuga Creek, Buffalo Creek and Smokes Creek.

Cayuga Creek is polluted below Lancaster and Depew with septic conditions occurring below Depew. The lower six miles of Cazenovia Creek is polluted by sewer discharges with dissolved oxygen dropping to zero at times.

The Buffalo River is grossly polluted. pH ranges from 2.8 to 10.4, dissolved oxygen frequently drops to zero resulting in septic conditions, phenol concentrations reach 2.27 mg/l, solids reach concentrations of 9,490 mg/l, and coliform counts exceed 2,500,000/100 ml at times. Oil, scum, debris and refuse accumulate, causing unsightly and hazardous conditions. Discharges of dyes and iron wastes cause a color problem in the river. No visible biological life exists in the Buffalo River.

Major sources of wastes are from the industries located on its banks.

Uses are restricted to navigation, industrial water (mostly cooling), and waste transport.

The Niagara River is polluted in a horizontally stratified zone near the shore. High phenol concentrations, oils, and high coliform counts characterize this polluted zone which extends about 400 feet from Birds Island in the vicinity of Buffalo's sewage treatment plant and widens to about one-third of the river's width near Strawberry Island. Pollution is fed into this zone by the Buffalo River, the harbor area, sewer outfalls, sewage plants and industries along the United States side.

Tonawanda Creek does not appear to have serious pollution problems although several industries and several towns discharge wastes into it.

So we see that pollution is continuously being poured into Lake Erie by rivers and streams. In addition, many municipalities and industries (many of them without adequate treatment) and combined sewers discharge directly to the Lake. Still more pollution comes in from Canada.

Now let us take a look at Lake Erie and see the effects of all this pollution on water quality and water uses.

Actually, Lake Erie is suffering from two pollution-caused ailments. One is caused by natural pollution from sun, wind, rain, erosion and organic growths, and by man-made pollution from cities, farms, industries and debris of civilization. This pollution is evident in such things as silted navigation channels and harbors, bacterial contamination, closed bathing beaches, and offensive sight and odor nuisances along the Lake's shores. The problems are especially acute near large centers of population.

The second ailment suffered by Lake Erie is a rapid increase in enrichment, mainly phosphorus and nitrogen, which results in undesirable changes in many forms of life. Tremendous growths of algae fed by nutrients are thought to be the direct cause of low dissolved oxygen in many bottom areas of Lake Erie. Low dissolved oxygen has both direct and indirect influences on fish life. Lack of dissolved oxygen eliminates spawning areas, makes large areas unsuitable for fish life, and drastically alters the amount and type of food available.

Toxic materials, silt, temperature, and other physical aspects are also believed to play a major role in the undesirable changes in Lake Erie.

Much of the American shoreline of Lake Erie out one to two miles is a polluted zone. Coliform counts decrease rapidly as one proceeds out into the Lake so that when one gets beyond the two mile zone counts are frequently near zero. Sediment high in organic matter near Toledo, Lorain, Cleveland and Buffalo causes unnatural growths of bottom organisms. Debris and algae washed ashore by winds and waves cause further damage to uses of inshore waters.

The most serious damage by pollution in this shoreline zone is to recreational uses, particularly to body contact uses such as bathing and skiing. Lakefront property is also devalued by limiting its use and general aesthetic appeal.

The areas hardest hit by this type pollution are: the Michigan shoreline, east of Toledo, Lorain, Cleveland, Silver Creek, Dunkirk and Buffalo.

The pollution comes from the rivers, from municipalities and industries discharging directly to the Lake, and from storm water runoff. The larger cities, Detroit, Toledo, Cleveland, Erie and Buffalo, and many smaller cities have combined sewer systems designed to carry both sanitary wash and storm runoff. Overflow devices are placed at strategic points so that overloaded sewers can discharge to the nearest surface drain during rains. Malfunctioning overflow devices and undersized sewers discharge raw sewage almost continually in some systems. Many sewage treatment plants discharging to the Lake only give primary treatment. Most chlorinate only during the summer, still others do not chlorinate at all.

Generally speaking, the bulk of Lake Erie beyond one to two miles from shore has water of excellent quality when compared to the standard water quality indicators used by sanitary engineers.

To get the real story on Lake Erie the sanitary engineer, the aquatic biologist and the fish biologist have to team up. As yet we do not have the full story but we do have a good start. First off we have come to realize that a large lake like Lake Erie has its own water quality needs. In other words, the geometry of the lake--size, shape, depth, et cetera--determines to a great extent the amount of certain pollutants it can handle.

Presently, we think phosphorus, nitrogen and sediment are the most important pollutants affecting the bulk of Lake Erie. (However, we do not as yet have enough knowledge of the effects of toxic materials to evaluate the part they play in the problem.)

An understanding of Lake Erie and its problems requires some knowledge of the Lake's structure. Lake Erie is approximately 250 miles long and about 60 miles wide. The Lake has three rather well defined bowls: a shallow bowl with a maximum depth of 54 feet and some islands in the western end; a central bowl with a gently sloping bottom having a maximum depth of 78 feet; and an eastern bowl with a maximum depth of 210 feet. As you will see later these three bowls or basins are almost like three different lakes biologically and to a small degree chemically.

Phosphorus and nitrogen produce large growths of algae or phytoplankton in Lake Erie which ultimately have a deleterious effect on water quality for many uses, especially fish life and fish food. A filamentous green algae, Cladophora sp., virtually prohibits the use of some beaches and shoreline areas at times. A strip of dead Cladophora 40 to 50 feet wide and 8 to 16 inches deep drifted onto the shoreline of Kelley's Island during the Summer of 1964. (This has occurred in the past at Kelley's Island, Erie, Pennsylvania, and on the New York shoreline). During the same period in the western basin, an algal bloom covering approximately 800 square miles produced a dense surface scum two feet thick with an appearance of split pea soup.

Dr. Charles Davis, Western Reserve University, reports that algal concentrations at the Cleveland Division Filtration Plant have increased by 3 to 4 times since 1946. Dr. Davis also reports that the predominant species of algae are gradually changing from low nutrient requiring types to those requiring higher concentrations.

Results of studies made in the island area between 1938 and 1942 by Stone Laboratory personnel compared to results of Public Health Service studies of 1964 show a similar change in species and increase in concentrations.

Chemical data, although a bit sketchy in the early 1900's, bear out this transition in water quality. Although practically all compounds have increased markedly percentage wise, nitrogen and phosphorus are the most significant because of their importance in stimulating algal and other aquatic growths.

Total nitrogen in the island area increased from 0.265 mg/l in 1942 to 0.83 mg/l in 1958; total phosphorus in this area increased from 0.014 mg/l in 1942 to 0.036 mg/l in 1959. These values correlate well with the changes in algae species and increases in algae growth. Data in the central and eastern basins are sketchy, however, they too show the same increasing trend.

Algae cause problems other than nuisance conditions. They can and do use up oxygen both by respiration and by exerting a biochemical oxygen demand after dying. Last August we found a 2,600 square mile area in the central basin that was practically devoid of oxygen (0 to 2 mg/l) beneath the thermocline, which was 3 to 10 feet off the bottom.[1]

Each year in August since 1959 similar conditions on about the same scale have been recorded by the Great Lakes Fishery Commission and the Great Lakes Institute of Toronto. The only data earlier than 1959 were recorded in August 1929 when an oxygen depression was noted in the same general area but was not nearly so severe, being 5.0 to 8.0 mg/l. The Great Lakes Institute of Toronto also observed these conditions in August 1964 in the central basin and found matching dissolved oxygen concentrations at similar depths in the eastern basin. They also recorded some dissolved oxygen values near zero in parts of the western basin in July 1964.

Dr. N. W. Britt reported severe oxygen depletions in the bottom waters of the western basin in the Summer of 1953. This condition practically eliminated the mayfly nymph population and subsequent occurrences of low dissolved oxygen have literally wiped out this species. Only those species of bottom organisms which are adapted to tolerate periods of low dissolved oxygen remain in most of the western basin.

A few years after the mayfly nymph and other pollution-intolerant organisms were almost completely wiped out, the walleye (pickerel) also virtually disappeared. This is still somewhat of a mystery story. Did the same physical conditions that brought on the low dissolved oxygen wipe out the walleye - did the low dissolved oxygen do it or was it the break in his food chain that wiped him out? Was it silt covering spawning beds? Could it have been a combination of these three or even could it have been toxic materials and not related? Well, we don't know yet, but we are still asking questions.

Bottom fauna studies made on the central and eastern basins found only organisms that can tolerate prolonged periods of less than 2.0 mg/l

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[1]A thermocline is a narrow transitional zone between the upper warm layer of water and the lower colder layer. The thermocline acts as a barrier, preventing mixing of the two layers, and also prevents oxygen transfer to replenish that used in the lower layer.

Thermoclines are common occurrences in bodies of water depending on depth and movement. The thermocline in the central and eastern basins usually develops in mid-June and lasts until September in the central basin and October in the eastern basin. The western basin thermoclines are very transient in nature, occurring only during extreme calm, hot weather.

of dissolved oxygen in the 2,600 square mile low dissolved oxygen area while a greater variety was found in the transition zone between the central and eastern basins where minimum dissolved oxygen concentrations were from 2 to 4 mg/l. Since the depth of the water beneath the thermocline in the eastern basin is greater and biological productivity is low, dissolved oxygen concentrations below 4.0 mg/l seldom occur. Because of this a wide variety of pollution sensitive bottom dwelling animals not found in the rest of the Lake, occur.

It is logical to assume that if present rates of increase in nutrient concentrations and algal productivity continue, it may not be long before the conditions now present in the central basin begin to occur in the eastern basin despite its greater depth.

Unfortunately, we have been unable to locate historical data on bottom fauna in the central and eastern basins. However, we think that recorded changes in the western basin correlated with known changes in algal growths and nutrient increases in the central and eastern basins are pretty good evidence that the conditions in these basins are also rapidly worsening. We know that increased nutrients are causing heavier algal growths, and we strongly believe that the organic growths are primarily responsible for the low dissolved oxygen in the bottom layers.

Evidence has been found to indicate that many fish actually die in these low dissolved oxygen zones. Certainly an area of 2,600 square miles would present quite a desert to a hungry fish especially if he didn't have sense enough to come up to where there is adequate dissolved oxygen.

Soon now, data from our intensive study will be in and evaluated. What then? First, where solutions to problems are obvious, remedial measures will be recommended. In fact, this procedure is being followed now and many problems are already being corrected. Second, let's take the technical standpoint. A technical base will be formed from which information necessary to making decisions on water quality can be drawn. What does this gobbledygook mean? It simply means that we will take the information from our study which is primarily data on sources and kinds of wastes and their effects on water quality and build two types of mathematical models - a water quality model and an economic or decision model. A mathematical water quality model is a mathematical formula encompassing the prime variables affecting water quality and can be used to describe the changes in water quality as any variable or group of variables are changed. By the use of such models on computers we are able to simulate conditions and thereby predict what will happen if certain controllable variables like waste loads and flows are changed. Thus, we can predict the effects of proposed control facilities without actually building them.